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Review article

The Spastic Hip in Children and Adolescents

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ABSTRACT

The hip is the joint most exposed to orthopaedic complications in cerebral palsy (CP) which is the main cause of spasticity in paediatric patients. The initial immaturity of the hip allows the forces applied by the spastic and retracted muscles to displace the femoral head, eventually causing it to dislocate. The risk of hip dislocation increases with the severity and extent of CP, exceeding 70% in the most severe cases. Hip dislocation causes pain in up to 30% of cases, carries a risk of orthopaedic and cutaneous complications, and hinders patient installation and nursing care. These adverse outcomes warrant routine screening, which has been proven effective in lessening the frequency and severity of hip displacement.

Preventive techniques including physical therapy, orthoses, and treatments to alleviate spasticity are strongly recommended in every case. The beneficial effects of treating spasticity, if needed via neurosurgical procedures, have been convincingly established.

Orthopaedic surgery is required when prevention fails. Soft-tissue release is designed to correct the asymmetry in the forces applied by the muscles. Femoral osteotomy creates the possibility for spontaneous correction of secondary acetabular dysplasia. Progress has been made in standardising the use of multilevel surgery involving the soft tissues, femur, and pelvis, which is often effective in correcting the morphological abnormalities and stabilising the joint. When hip pain or alterations are severe, hip resection or total hip arthroplasty are highly effective in alleviating the pain and improving patient comfort. The spastic hip is a complex condition in which currently available screening protocols and treatment strategies have been proven effective in benefitting patient outcomes.

Key words: Cerebral palsy. Hip dislocation. Spasticity. Neurological hip. Hip surgery.

INTRODUCTION

Hip abnormalities that develop in childhood due to neurological disorders constitute a major challenge for orthopaedic surgeons in both paediatric and adult practice. In adult orthopaedics, the devastating consequences of neurological hip disorders in a young adult presenting with pain and discomfort are a dreaded occurrence that raises complex therapeutic dilemmas. In paediatrics, in contrast, the challenges, disappointments and successes associated with neurological hip disorders are part of daily practice. The many published case-series and the commitment of specialised medical and surgical teams have provided valuable new insights. Screening protocols and treatment strategies have improved.

Both spasticity and flaccid paralysis can affect the hip. This lecture focuses on spastic hip dislocation (SHD), whose predominant aetiology by far is cerebral palsy (CP). Hip dislocation related to flaccid paralysis is far less common, due in part to the elimination of anterior poliomyelitis from industrialised countries, and will not be discussed here, as the management varies across the broad range of underlying neurologic and muscular dystrophy aetiologies.

Using practical issues as starting points, this lecture highlights a number of indicators that provide orientation for the detection and treatment of patients with SHD.

1. SCREENING STRATEGIES FOR SPASTIC HIP DISLOCATION (SHD)

1.1. Current concepts on the natural history and pathophysiology of spastic hip dislocation (SHD)

A first prerequisite to the development of screening and prevention strategies for health conditions is a good understanding of the pathophysiological mechanisms involved in SHD. A second prerequisite is knowledge of the potential benefits to the individual patient and community of implementing screening and prevention protocols. Accurate estimates are available of the incidence of hip dislocation according to the severity of the neurological impairment, particularly in CP, which is the leading cause of pyramidal syndrome in paediatric patients. CP affects about 2/1000 neonates in western countries, and premature birth is the main cause. Progress has been achieved in identifying the populations that require routine screening. In a recent epidemiological study: “EPIPAGE-2”, the prevalence of diagnosed CP at 2 years of corrected age decreased with increasing gestational age at birth, from 6.9% at 24-26 weeks to 4.3% at 27-31 weeks, and 1% at 32-34 weeks (1).

The muscle forces applied to the hip have received only limited research attention. The immaturity of the hip at birth is a crucial factor. As with developmental dislocation of the hip, the largely cartilaginous and fibro-cartilaginous tissues in the hip respond to external mechanical forces by undergoing gradual distortion. Mechanical forces, which are applied continuously and increase with age, also impair the growth of the joint, causing anatomic alterations. The result is secondary dysplasia of the acetabulum, which is shallow, widened and abnormally oriented; and deformities of the proximal femur, consisting mainly in abnormal femoral anteversion (2). A 2015 study by Chang et al. demonstrated a strong correlation between hip adductor contracture and femoral head displacement, when femoral anteversion was related to muscle spasticity (3). A major role has been established for bi-articular muscles that most strongly express spasticity, such as the hamstrings and the iliopsoas muscle (4, 5). Although the effects of spasticity on muscle remain unclear, tissue alterations due to spasticity seem to underlie the development of contractures (6). Thus,

spasticity and contractures impair the ability of muscles to adapt to skeletal growth, thereby causing hip dislocation.

Studies assessing the impact of femoral head displacement on the acetabulum consistently showed overall deterioration in the anterior-to-posterior direction due to the forces applied to the acetabulum by the excessively anteverted proximal femur (7). The acetabulum widens and splays open, thereby increasing in capacity (i.e. volume). The resulting mismatch with femoral head size, which remains small, promotes migration of the head. The severity of this secondary acetabular dysplasia correlates with CP severity and with the occurrence of gradual femoral head migration but not with the amount of migration (e.g., severe dysplasia may coincide with minimal migration and conversely) (8).

The risk of developing SHD in CP has been extensively investigated. In a 2012 study by Terjesen in 335 children with CP, the prevalence of a femoral head migration percentage greater than 33% was 26% overall (9). Among patients at GMFCS¹ levels IV and V, 45% and 72% of the patients, respectively, had hip subluxation or dislocation (dislocation rates were 3% and 17%). The risk of migration or SHD increased with the severity of the functional impairment, from 1% to 72% at GMFCS levels I to V. Furthermore, the risk increased with extension of the disease from 3% in patients with hemiplegia to 81% in those with quadriplegia. CP types characterised by abnormal movements carry a lower risk of 26% in dyskinesia and 0% in ataxia. (9). The rate of MP progression is higher in the more severe forms, ranging from 0.2%/year in the GMFCS I group to over 9.5%/year indicating rapid femoral head displacement in the GMFCS V group. Similarly, another study showed that age at subluxation or SHD decreased as the severity and extent of CP increased and that the incidence of subluxation and SHD increased with age (10).

¹ GMFCS: Gross Motor Functional Classification Scale (Palisano RJ, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and validation of a gross motor function classification system for children with cerebral palsy. *Dev Med Child Neurol* 1997; 39: 214–23).

1.2. Consequences of femoral head migration in patients with cerebral palsy (CP)

SHD is associated with severe morbidity. **Pain** is the main concern. Among patients with subluxation or SHD, 29% have hip pain at 9.5 years of age and this proportion increases to 72% in young adults at high GMFCS levels. Pain is a major cause of progressive quality-of-life impairment over time (11). The prevalence of quality-of-life impairments increases both over time and with the severity of the hip alterations (MCPHCS² grades 4 and 5).

Other factors may have a major influence on the development or progression of hip displacement. Muscle asymmetry, hip displacement, pelvic obliquity, and neurological scoliosis may be related to one another (12). Nevertheless, the underlying pathophysiological mechanism has not been identified. Unilateral dislocation may be associated with pelvic obliquity, but whether scoliosis with pelvic obliquity influences the development of hip dislocation remains unclear (13, 14).

The surgical treatment of SHD raises several issues. In addition to technical difficulties, the risk of recurrent dislocation and/or bone deformity is high and increases with decreasing patient age (15). However, the recent introduction of screening strategies can be expected to benefit the early diagnosis, thereby improving long-term outcomes. Recent published studies indicate that non-operative treatments or limited surgery (i.e. soft tissues release) used early in patients identified by screening are effective in decreasing the frequency and severity of hip dislocation (16).

² MCPHCS: Melbourne Cerebral Palsy Hip Classification Scale (Robin J, Graham HK, Baker R, et al. A classification system for hip disease in cerebral palsy. *Dev Med Child Neurol* 2009;51:183-192).

1.3. Current screening strategies for spastic hip dislocation (SHD)

- 1.3.1. *Screening should be implemented by healthcare professionals* involve in managing CP patients (i.e. rehabilitation physicians and specialised paediatricians). Paediatric orthopaedic surgeons should be involved early in the **multidisciplinary follow-up** of these patients, especially when they are at risk for hip dislocation.
- 1.3.2. *Screening rests on regular physical examinations and radiological assessments* to detect hip displacement at a very early stage. Muscle asymmetry is readily identified and, although not fully reliable, the physical examination is the first-line screening tool for hip displacement (3, 10). In 1980, Reimers described the Migration Percentage (MP) as a reliable and reproducible radiological parameter for measuring femoral head displacement relative to the centre of the acetabulum (Figure 1) (17). Other parameters have been described but remain controversial (18). However, the MP does not reflect the possible presence of secondary deformities of the femoral head and acetabulum. Thus, the MP should be viewed as a screening tool and not as part of the pre-operative work-up (8). Hagglund et al. reported that an MP greater than 33% indicates a need for surgical treatment (19). The Melbourne Cerebral Palsy Hip Classification Scale (MCPHCS) is a recently developed classification for hip deformities based on morphological criteria (supplemental appendix 1). The MCPHCS allows comparisons of the deformities and assesses the severity of the hip alterations, from normal (grade I) to alterations requiring resection of the proximal femur (grade VI). However, this scale remains only descriptive of the radiological bone deformities.

1.4. Screening strategy

Two types of strategy have been suggested. One links screening to the treatment approach, with the aim of achieving early hip displacement correction to avoid progression to hip dislocation. Registries on this approach have been set up in Sweden and Norway (<http://cpup.se/in-english/>). Hägglund et al. reported the results in 2005 then, in 2014, very good outcomes with up to 20 years' follow-up (16). The follow-up strategy includes yearly physical and radiological assessments starting at 2 years of age. Treatment is offered as soon as the MP reaches 10% and ranges from simple non-operative measures to surgery.

The second strategy was developed by the Australian Academy of Cerebral Palsy and Developmental Medicine³. Criteria were selected based on known risk factors for SHD then updated in the light of the data accumulated over the first 5 years. The strategy consists only in determining the optimal screening interval according to the severity of CP and level of risk. It does not involve treatment suggestions (20) (document available at <https://www.aacpdm.org/UserFiles/file/IC292.pdf>) (Figure 2, supplemental appendix 2).

Professional societies should promote the dissemination of these strategies. The Pediatric Orthopedic Society of North America (POSNA) reported that 93% of physicians involved in the care of patients with CP agreed that a monitoring programme was needed but that only 18% applied such a programme in their clinical practice (21).

In France, the main healthcare network focussing specifically on paediatric rehabilitation care (R4P, *Réseau Régional de Rééducation et Réadaptation Pédiatrique en Rhône-Alpes*, <http://www.r4p.fr/>) has been promoting hip screening since 2011, when publishing practice guidelines on hip displacement in children with CP (supplemental appendix 3).

³AusACPDM, <https://www.ausacpdm.org.au/>

2. RECENT ADVANCES IN THE TREATMENT OF SPASTIC HIP DISLOCATION (SHD)

2.1. Is there still a role for non-operative treatment?

Non-operative treatment may deserve discussion at two stages of the disease:

2.1.1. *Incipient hip displacement*

Evidence indicates that non-operative treatment should be used first in patients with incipient hip displacement (MP<30%, MCPHCS III). Efficiency of the treatment must be assessed after a few months. The basics of non-operative treatment, such as passive stretching and postural orthoses, will not be discussed here. Treatments alleviating spasticity include botulinum toxin, intrathecal baclofen (ITB), and selective dorsal rhizotomy (SDR) and may significantly diminish the need for orthopaedic surgery. Although their effects are still debated, these treatments are now an integral part of the therapeutic decision-making process (22, 23).

2.1.2. *Complete hip dislocation*

Whether surgery should be considered routinely in non-ambulatory patients (GMFCS IV and V) with complete hip dislocation (MCPHCS V) deserves discussion. Non-operative preventive treatment targeting pain and mobility is sufficient in patients with bilateral hip dislocation but without pain, muscle asymmetry, discomfort, or nursing care difficulties. Surgery is indicated in this situation only to achieve a well-defined objective, such as ensuring patient comfort or facilitating nursing care. In addition, the appropriateness of

performing surgery must be discussed according to the general health of the patient.

2.2. Current data on surgical treatments of SHD

2.2.1. Soft tissue release

Soft tissue release aims to eliminate the deleterious effects of muscle contractures on the hip. The procedure must be planned with great care to ensure lasting or definitive muscle symmetry avoiding new muscle imbalance. Thus, bilateral and asymmetrical release is usually needed. Adductor, iliopsoas, and medial hamstring muscles are the main muscles involved in surgery. The outcomes are best in patients who are at low GMFCS levels and have limited hip displacement (24, 25). It is worth emphasising that soft tissue release must be considered routinely when surgery is planned to treat SHD or increasing MP (i.e., subluxation) (26).

2.2.2. Concomitant partial neurotomy or neurectomy of the adductor muscles

The main risk associated with this procedure is postoperative muscle imbalance with overcorrection, contralateral hip dislocation, or conversion of posterior to anterior or inferior hip dislocation. This risk and the challenges raised by predicting the net effect of the combined soft-tissue and neurological procedures now considerably limit the use of this technique.

2.2.3. Combination with neurosurgical procedures

A recently suggested approach consists in combining definitive surgical treatment of spasticity with orthopaedic surgical treatment of CP-related disorders. Recurrence of the

deformities is common after orthopaedic surgery alone, and spasticity is a major risk factor for recurrence, as convincingly demonstrated for the recurrence of femoral torsion deformities (15, 27). Neurosurgical treatments for spasticity should therefore be considered in this situation.

2.2.4. *Bony surgery alone or combined with soft tissue surgery*

The aim of such surgery is to restore joint anatomy features that are as close to normal as possible and unlikely to change over time. Bony procedures should be consistently combined with soft tissue release to ensure optimal muscle balance. These procedures are indicated in patients with hip subluxation (MP>40%, MCPHCS VI) or recent hip dislocation (MCPHCS V). To achieve lasting stability, the femoral head must be properly centred in the acetabulum and the joint surfaces must be congruent. Preoperative computed tomography (CT) is valuable to ensure that these objectives can be met.

The first issue is whether surgery should be **unilateral or bilateral** in patients with unilateral SHD. Unilateral surgery carries non-negligible risks of recurrent dislocation and contralateral hip destabilisation. Whereas the influence of pelvic obliquity and scoliosis remains poorly understood (13, 14), convincing evidence exists that muscle release should be performed bilaterally, either alone or during hip repositioning surgery (28). After unilateral surgery, 44% of the patients re-evaluated by Canavese et al. at skeletal maturity had required bony surgery on the contralateral hip (27). Thus, when performing unilateral bony surgery, and except when the contralateral hip is strictly normal, at least bilateral soft tissue release should be performed. When the contralateral hip is “at risk” (MP between 10% and 30%, MCPHCS II or III) or the patient has pelvic obliquity or a GMFCS level between III and V, primary bilateral bony surgery seems at least, reasonable, indeed advisable (21, 27, 28).

2.2.4.1. Femoral varus derotation osteotomy with iliopsoas muscle avulsion (i.e. apophysis detachment) or tenotomy performed alone or with soft tissue release does not consistently ensure permanent stabilisation of the dislocated spastic hip. High rates of recurrence or repeat surgery of up to 74% have been reported (15). Nevertheless, when performed bilaterally before 6 years of age in patients with limited hip displacement (MCPHSC II or III) and intermediate GMFCS levels (II-IV), this procedure seems to provide good outcomes in terms of hip stability and acetabular development (29). The osteotomy must mainly correct the anteversion and produce a moderate degree of varus ($120^{\circ} \pm 10^{\circ}$). In our opinion, two factors determine whether the femur should be shortened concomitantly, namely, the amount of upwards femoral head migration and whether pelvic osteotomy is required. This procedure carries an up to 46% risk of avascular necrosis of the femoral head, a complication for which no clear-cut risk factors have been identified (30). Shortening may prevent avascular necrosis of the femoral head.

2.2.4.2. Most of the recent studies showed good outcomes after multilevel surgery combining soft tissue release, femoral osteotomy, and pelvic osteotomy. Whether performed unilaterally or bilaterally, multilevel surgery was associated with significantly lower recurrence rates in many studies (31). We use the method described by Huh et al. in 2011 and consisting in performing a femoral osteotomy then obtaining intra-operative imaging studies to determine whether a pelvic osteotomy is in order (32). The peri-acetabular pelvic osteotomy techniques (Pemberton, Dega, or modified Dega ["San Diego"]) appear to be the most effective in correcting secondary acetabular dysplasia and restoring concentricity (7, 8, 33) (Figures 3 and 4). Rotational or augmentation pelvic osteotomy techniques are less often used. Acetabular enlargement (shelf osteotomy or Chiari osteotomy) must be reserved for cases

where restoring hip concentricity is not feasible because of the anterior-to-posterior acetabular secondary dysplasia. Rotational osteotomies (Salter, Pol Le Coeur triple osteotomy) have been associated with posterior uncovering of the femoral head and cannot be advocated. Capsulorrhaphy does not seem necessary.

2.2.4.3. Quality of life

Despite the risk of recurrence or complications related to the underlying disorder, which requires a long-term monitoring and prevention strategy, bony and multilevel surgical procedures seem warranted based on their ability to **significantly improve quality of life** (comfort, pain, installation, feeding, and communication). The gains are particularly great in patients with marked hip displacement and severe pain (34).

2.2.5. *Long-standing hip dislocation and/or severe hip dysplasia*

At this stage, deformity or degenerative lesions of the femoral head are common (MCPHCS IV or V). Long-standing unilateral hip dislocation without hip pain can nevertheless exacerbate orthopaedic complications (i.e. scoliosis).

2.2.5.1. Bilateral **painless** hip dislocation in non-ambulating patients

In the absence of other factors of adverse significance, surgery is not indicated in these patients. However, in patients with unilateral or bilateral SHD, the development or worsening of orthopaedic abnormalities, patient discomfort, or nursing care difficulties indicates a need to consider surgery. In young patients whose triradiate cartilage is still open, “combined” surgery is warranted (see 2.2.4). Once skeletal maturity is achieved, either acetabular enlargement (shelf osteotomy or Chiari osteotomy) combined with a femoral

osteotomy and/or soft tissue release can be performed. Total hip arthroplasty was suggested recently in this situation (see below) (35).

2.2.5.2. Severe hip dysplasia in ambulatory patients

This condition induces the same problems with pelvic balance as do muscle contractures, pelvic obliquity, and limb length discrepancy. The causes should be treated. Selection of the bony procedure is guided by the nature of the bone deformities, as with surgery to treat developmental dysplasia: femoral osteotomy appropriate to correct the deformity and pelvic osteotomy as required by the dysplasia and hip displacement.

2.3. New prospects for surgical treatment

The treatment of long-standing and/or painful SHD in patients with CP can be expected to benefit from the growing experience with **total hip arthroplasty (THA)**. Compared to the general THA population, ambulatory patients with CP do not seem at significantly increased risk of adverse outcomes (36). The situation is very similar when THA is performed in non-ambulatory patients with CP, despite the frequent presence of severe pain and poorer general health condition. Nevertheless, a few specific features are worth noting: the risk of dislocation and early revision surgery is higher; the risk of infection is not significantly different provided standard precautions are taken; and heterotopic ossifications, although not more common, are more severe. The THA survival rate is very good, reaching 77% after 10 years (36). Survival rates are best with prostheses that are fully cemented or have a cemented femoral component and press-fit cup. Many patients require extensive soft tissue release and/or bone grafting. The optimal friction couple is controversial. Although a metal-polyethylene couple seems reasonable, ceramic implants do not seem associated with

a higher fracture risk. Dual-mobility cups are believed to lessen the risk of secondary dislocation, particularly in patients with CP. Implant size must be carefully selected before surgery, and the slender osteoporotic bones of patients with CP can require the use of custom-designed implants (37). In 2016, Silverio et al. suggested using the humeral component of shoulder prosthesis with good results (38). After surgery, the hip is preferentially immobilised in a cast for 3 to 6 weeks to limit the risk of complications. If untreatable complications develop (i.e. infection or THA loosening), removal of the prosthesis amounts to a joint resection (Figure 5).

3. MANAGEMENT OF THE PAINFUL SPASTIC HIP

3.1. Diagnosing the painful spastic hip

Among patients at GMFCS levels IV and V, about 30% have painful hip displacement. Daily nursing care procedures cause pain. In patients with little ability to communicate, a change in behaviour or refusal to eat should be taken as a warning sign. Specific tools are available for assessing pain in non-communicating patients. The diagnosis is confirmed by an antero-posterior pelvic radiograph taken in the supine position with the lower limbs aligned and the patella facing upwards.

The amount of hip displacement does not correlate with pain severity. Analgesics and other measures aiming at relieving pain are essential as soon as the diagnosis is established. In our experience, in addition to level II to III analgesics, botulinum toxin injections provide temporary pain relief. The injections can be repeated at short intervals, targeting the spastic muscles involved in dislocation (iliopsoas, rectus femoris, medial hamstring, and adductor muscles). We found also that pre-operative botulinum toxin decreased the duration of post-

operative pain (39). Botulinum toxin therapy can thus improve the symptoms while waiting for adapted surgery (35). Intra-articular injections of corticosteroids and local anaesthetics (ropivacaine) may provide additional relief, at the cost of an increased risk of joint infection.

3.2. Available treatments for the painful spastic hip

The impact of hip pain and patient discomfort are crucial issues (40). Treatment decisions depend on patient-related factors (general health, functional prognosis, and local status), pain intensity, and hip dislocation severity. When surgery is considered, the timing of the procedure depends on the response to non-operative treatment: if the response is inadequate or absent, the patient's status worsens, with increasing pain, and both the surgical procedure and the post-operative course become increasingly difficult. The femoral head becomes deformed and its surface undergoes degenerative changes. As a result, weight bearing after conservative surgery carries a high risk of persistent or exacerbated pain. Magnetic resonance imaging is valuable in this situation to assess the damage to the femoral head.

3.2.1. Conservative surgery

We do not recommend femoral head repositioning in patients with severely dysplastic and severely painful spastic hip. However, others have reported satisfactory outcomes at this stage of the disease. We believe that the risk of revision surgery due to persistent or exacerbated pain makes salvage procedures preferable (see below) (35). Repositioning procedures (femoral osteotomy and acetabular augmentation – shelf osteotomy (41), Chiari osteotomy(42), or rotational osteotomy [i.e. Salter or triple pelvic osteotomy]) should be reserved for patients with only moderate damage to the femoral head (35).

3.2.2. *Femoral resection*

Femoral resection procedures have a poor reputation. Although not the least effective, they carry a non-negligible risk of complications. Techniques include complete resection of the proximal femur to below the lesser trochanter(43), simple femoral neck excision, and Schanz proximal femoral valgus osteotomy. In some patients, these techniques have been combined with muscle reconstruction (44). We use simple femoral neck excision combined with sub-trochanteric valgus osteotomy (45). The outcomes are almost consistently favourable, particularly in terms of pain and mobility, albeit variably regarded in the literature. The main reported complications are upwards migration of the proximal femur (uncommon); heterotopic ossification (in 20% of cases on average) often with little disability (in the absence of ankylosis); and revision surgery (in up to 24% of cases). Measures designed to prevent heterotopic ossification such as immobilisation and radiation therapy have not produced convincing evidence of efficacy in patients with CP. Severe pain is common in the post-operative period, except when botulinum toxin is used pre-operatively and immobilisation provided post-operatively (35, 46, 47) (Figure 6).

3.2.3. *Hip arthrodesis*

Hip arthrodesis is the procedure associated with the poorest tolerance and worst outcomes and should therefore be performed only as a procedure of last resort (35). To anticipate patient positioning, the need for spinal fusion to treat scoliosis must be assessed. Scoliosis surgery may turn out to be the priority.

4. CONCLUSION

New insights into the pathophysiology and potential complications of SHD in children

have led to the development of routine screening protocols and to the improved standardisation of treatment strategies. Several approaches have been described and found effective. Physicians now need to incorporate these approaches into their practice to the advantage of their patients (Figure 7). Non-operative treatment deserves renewed attention, as botulinum toxin therapy to alleviate the spasticity is now widely available. Soft tissue release is required when hip displacement occurs ($MP \geq 30\%$, MCPHCS III or IV) despite appropriate prevention measures. In our opinion, bilateral surgery is clearly required when the contralateral hip is at risk ($MP \geq 20\%$) or in case of pelvic obliquity with a high risk of subsequent destabilisation. Bony surgery is mandatory in patients with marked hip displacement ($MP > 40\%$, MCPHCS IV). Selection of the bony procedure is guided by the patient's age and, most importantly, the duration of the dislocation and damage to the femoral head. At the acetabulum, reconstruction is currently the best option, the goal being to restore congruity and concentricity of the joint using peri-acetabular osteotomies. When this goal is not achievable, conservative procedures such as a shelf osteotomy or Chiari osteotomy should be reserved for hips with little or no evidence of degenerative changes. In practice, this is the case of hip displacement that is not painful but causes nursing care difficulties or induces a risk of additional orthopaedic abnormalities (scoliosis). In patients with hip pain and femoral head damage (long-standing dislocation), we believe that the procedure of choice is femoral neck excision combined with valgus osteotomy, preferably on both sides to avoid destabilisation. Finally, the accumulation of data demonstrating the efficacy and good tolerance of THA is opening new perspectives. We believe that THA is clearly indicated in patients with a good potential for mobilisation or verticalization to allow transfers. In patients with severe spasticity, the need for neurosurgical treatment must always be considered before performing orthopaedic surgery.

The tools and techniques available today are likely to decrease the number of surgical

procedures required and the complexity of the situations encountered in patients with CP.

Reliable procedures exist, as well as reasonably sound evidence that they provide meaningful improvements. Nevertheless, neuro-orthopaedic surgery requires in-depth knowledge of the therapeutic indications and practical modalities of pharmacological treatments, including the administration of botulinum toxin.

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FIGURE LEGENDS

Figure 1: Measurement of the migration percentage described by Reimers: A/B reflects the percentage of hip displacement

Figure 2: Personal interpretation of the AusACPDM guidelines in Winter M, Gibson N, Kentish M, Love SC, Thomaso P, Willoughby K and Graham HK, Australian hip surveillance guidelines for children with cerebral palsy, 2014, downloadable at <https://www.aacpdm.org/UserFiles/file/IC292.pdf>

Figure 3: 11.5-year-old boy with GMFCS V tetraplegic cerebral palsy. Recent dislocation of the right hip (a); bilateral repositioning surgery (b) with soft tissue elongation, femoral varus-derotation osteotomy, and modified Dega (San Diego) peri-acetabular osteotomy; and (c) outcome at skeletal maturity

Figure 4: 9-year-old girl with GMFCS III spastic tetraplegic cerebral palsy: (a) gradual hip displacement; (b) repositioning surgery involving multiple tenotomies, varus-derotation femoral osteotomy, and modified Dega (San Diego) osteotomy at the left acetabulum; and (c) outcome at 13 years of age before hardware removal

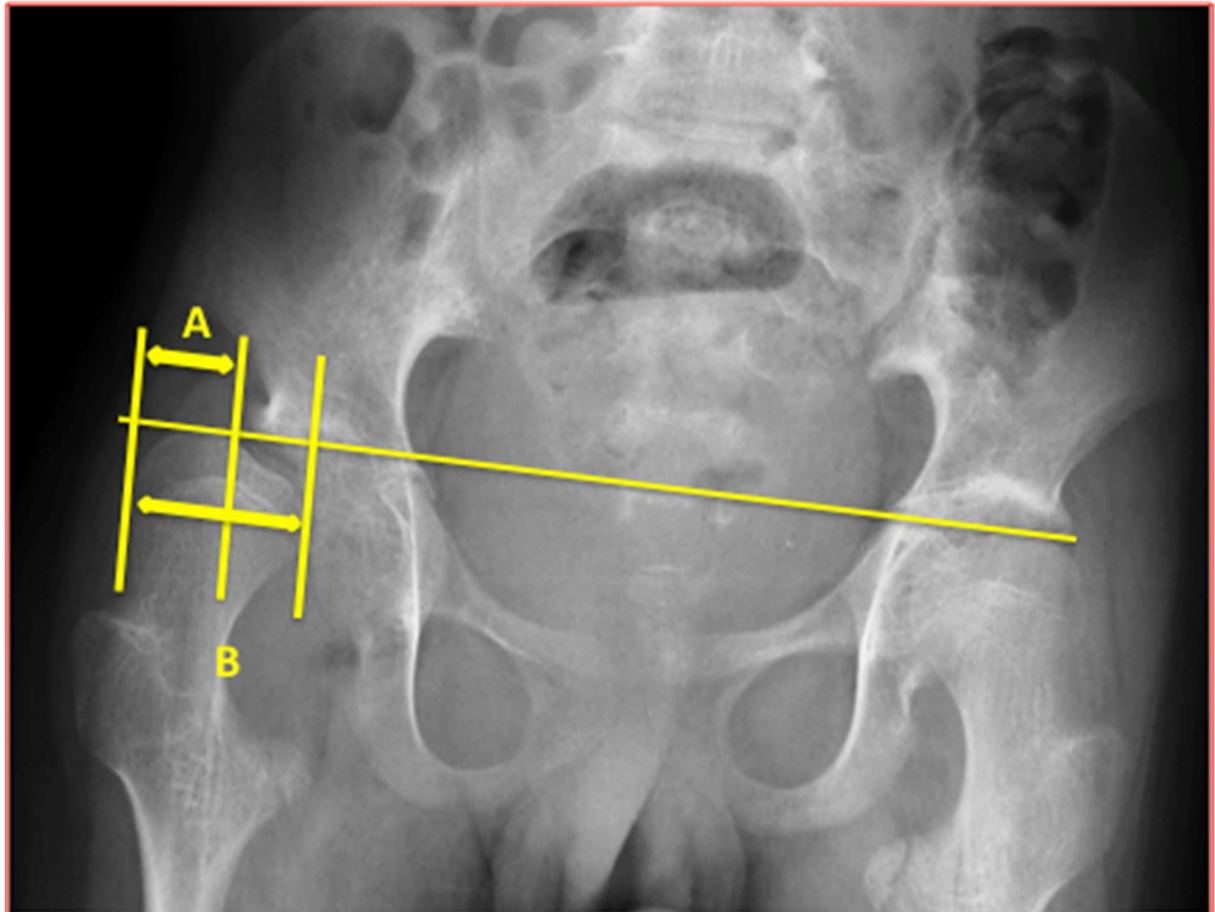
Figure 5: Patient with GMFCS V spastic tetraplegic cerebral palsy, painful dislocation of the left hip, and scoliosis. (a) Dislocation at 15 years of age, total hip arthroplasty on the left (press-fit dual-mobility cup with screw fixation, dysplastic femoral component), and (c) scoliosis surgery at 17 years of age

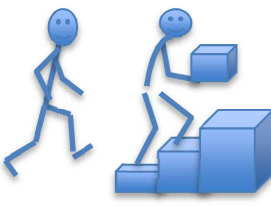
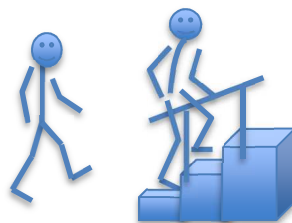
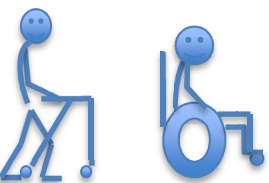

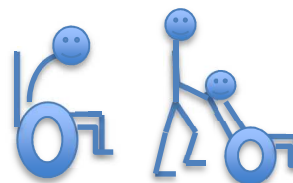

Figure 6: 7-year-old with severe encephalopathy, spastic tetraplegia, and bilateral long-standing painful hip dislocation. (a) initial radiograph; (b) resection of the femoral head and neck and valgus osteotomy; note the surgical cement plug used to seal the femoral neck section; outcome after 2 years

Figure 7: Suggested decision tree based on the amount of hip displacement, bone maturity, and pain

TTT: treatment

Figure 1 :



GMFCS I 	GMFCS II 	GMFCS III 	GMFCS IV 	GMFCS V 	WHH Type IV hemiplegia 
<p>- Initial assessment at 12-24 months of age (or at presentation): clinical assessment and AP pelvic radiograph</p> <p>- At 3 years of age: GMFCS I confirmed: simple clinical assessment then review GMFCS level at 5 years of age</p> <p>If WGH IV hemiplegia or GMFCS level >1, see recommendations for the confirmed level</p> <p>- At 5 years of age: If GMFCS I, clinical assessment; if normal, no further tests or radiographs</p> <p>If WGH IV hemiplegia, same as at 3 years of age</p>	<p>- Initial assessment at 12-24 months of age (or at presentation): clinical assessment and AP pelvic radiograph</p> <p>- Review 12 months later: GMFCS II confirmed, clinical assessment and AP pelvic radiograph</p> <p>If MP is abnormal, continue 12 monthly clinical and radiographic surveillance until stability is established. If MP is normal, assess at 4-5 years of age: clinical assessment and radiograph, If MP is stable, review at 8-10 years of age then at puberty</p> <p>If the GMCFS level has changed or WGH IV hemiplegia, ongoing surveillance according to confirmed classification</p> <p>In the presence of pelvic obliquity, leg length</p>	<p>- Initial assessment at 12-24 months of age (or at presentation): clinical assessment and AP pelvic radiograph</p> <p>- Review 6 months later: GMFCS III confirmed: clinical assessment and AP pelvic radiograph</p> <p>If MP is abnormal and/or unstable, 6 monthly clinical assessment and AP pelvic radiograph until MP stability is established then reduce frequency to once every 12 months until skeletal maturity</p> <p>- At 7 years of age: if MP stable and <30%, stop surveillance until puberty. If MP >30%, 12 monthly surveillance until maturity. Then, if pelvic obliquity, leg length discrepancy, or gait deterioration, continue 12 monthly surveillance</p>	<p>- Initial assessment at 12-24 months of age (or at presentation): clinical assessment and AP pelvic radiograph</p> <p>- Review 6 months later: if GMFCS IV confirmed, clinical assessment and AP pelvic radiograph</p> <p>If MP is abnormal and/or unstable, 6 monthly clinical assessment and AP pelvic radiograph until MP stability is established then reduce frequency to once every 12 months until skeletal maturity</p> <p>- At 7 years of age: if MP stable and <30%, stop surveillance until puberty. If MP >30%, 12 monthly surveillance until maturity.</p> <p>If scoliosis or pelvic obliquity is present, 6 monthly surveillance until maturity. Then, if MP is</p>	<p>- Initial assessment at 12-24 months of age (or at presentation): clinical assessment and AP pelvic radiograph</p> <p>- Review 6 months later: if GMFCS V confirmed, clinical assessment and AP pelvic radiograph</p> <p>If MP is abnormal and/or unstable, 6 monthly clinical assessment and AP pelvic radiograph</p> <p>- At 7 years of age: if MP stable and <30%, 12 monthly surveillance</p> <p>If scoliosis or pelvic obliquity is present, 6 monthly surveillance until maturity. Then, if MP is abnormal, 12 monthly</p>	<p>WGH IV hemiplegia carries a risk of delayed dislocation. Initial clinical assessment and AP pelvic radiograph then repeat at 5 years of age</p> <p>If MP is normal or stable, review at 10 years of age. Then, if MP is abnormal or unstable, 12 monthly surveillance until stability is established and/or until skeletal maturity</p> <p>At skeletal maturity, if scoliosis, pelvic obliquity, leg length discrepancy, or gait deterioration is present, 12 monthly surveillance</p>

	discrepancy, or deterioration of gait: 12 monthly surveillance		abnormal, 12 monthly surveillance	surveillance	
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Figure 2

Figure 3 :

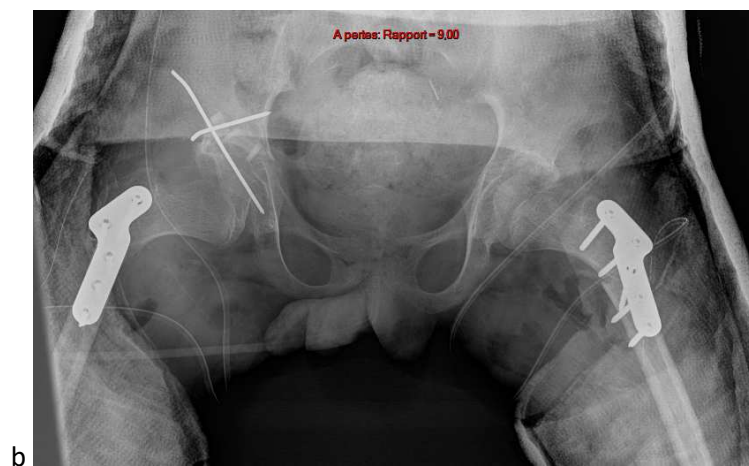
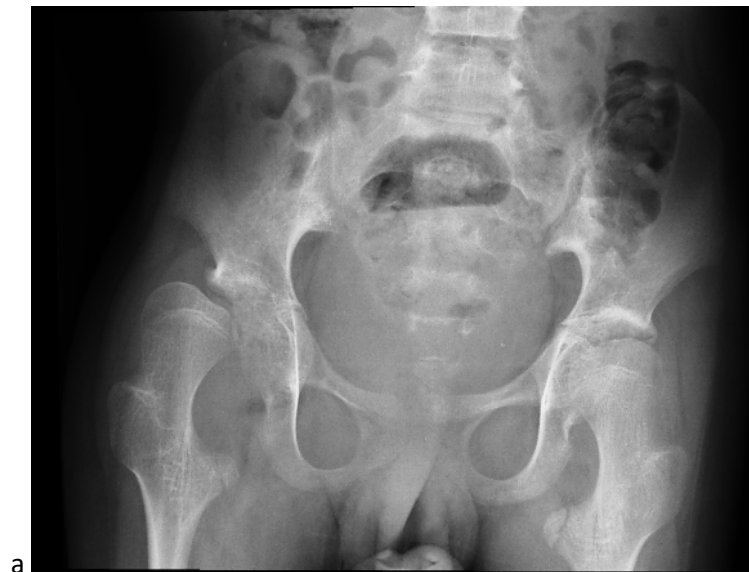


Figure 4

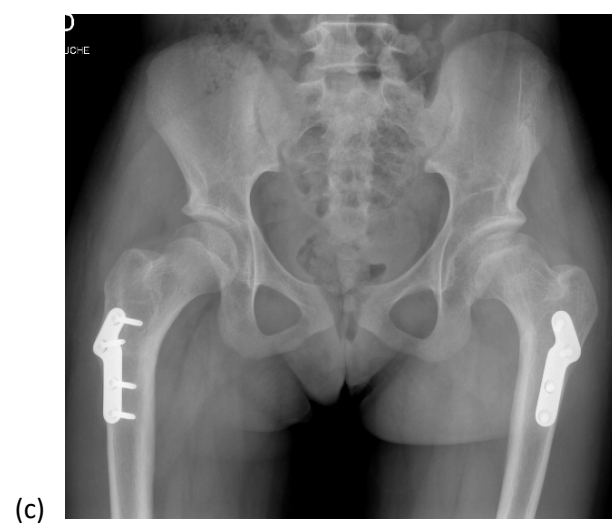
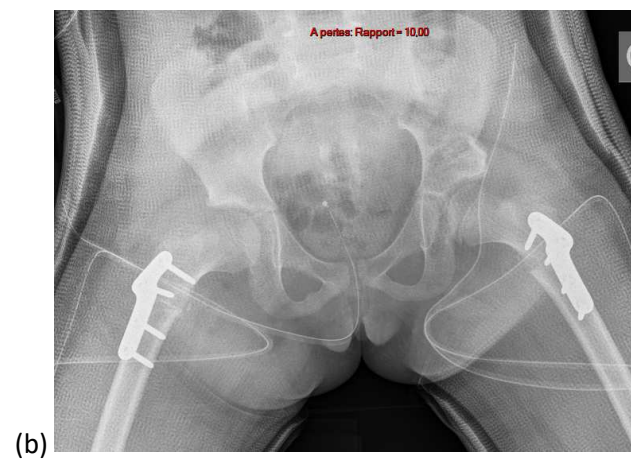
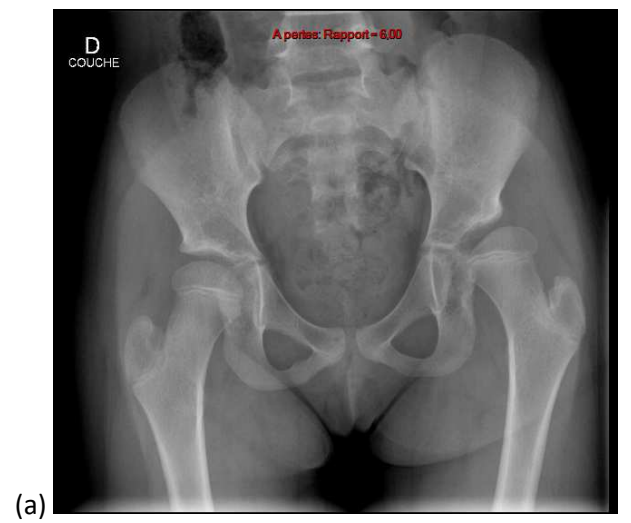


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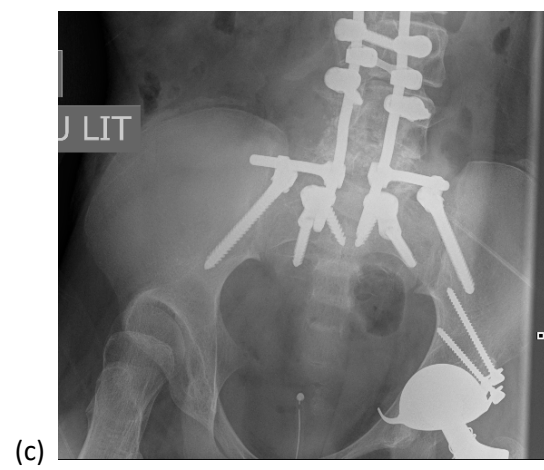
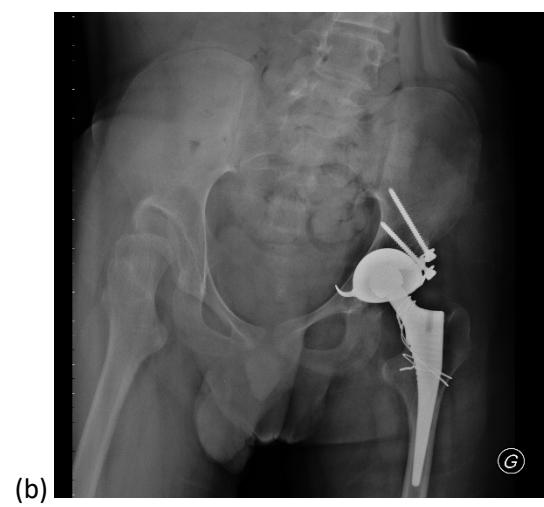
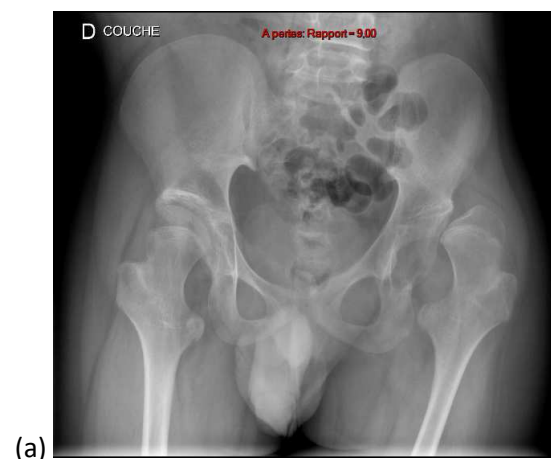


Figure 6 :



